Title: SAFETY EVALUATION OF RAMP METERING IN GLASGOW, SCOTLAND

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Introduction

As part of the EU DGXIII 'TA*BASCO*' (Telematics Applications in BAvaria SCotland and Others) project, the Technical University of Crete have developed for Glasgow City Council and The Scottish Office developed an integrated urban control strategy. This strategy, known as the IN-TUC strategy, uses ramp metering, variable message signing and urban traffic control to manage a diversion away from the motorway network at times of severe congestion. The overall project objective was to demonstrate integrated control by achieving overall network capacity maximisation. However, ramp metering, being a tool capable to manage the interaction of traffic at the motorway merge point, was seen as potentially offering significant traffic safety benefits. Traffic safety is a prime motivation for transport improvements within Glasgow and it was therefore of primary importance to study the potential impact upon safety of the control tools developed as part of the overall evaluation.

This paper describes the application of ramp metering, evaluates the network effects of ramp metering and develops a safety hypothesis which is investigated using image processing. This paper concerns data collected before the implementation of ramp metering only. A comparison of data both before and after ramp metering will be presented at the ICTCT conference in November 1997.

Glasgow

Glasgow is the largest city in Scotland, having a population of 625,000, within a conurbation of 1.7 Million. It has responded to the decline in traditional heavy industries (e.g. ship building) and adapted to become one of the foremost business centres in the UK, now possessing both a buoyant industrial and service sector. Its success is assisted by high quality transport links to outlying areas. It has an international airport located some 13 Km west of the city centre and is at the heart of the national motorway network. Within the urban area the city is served by a capacious local road network and a comprehensive public transport service, including underground trains. The city and its surrounding area benefits from the largest rail network in the U.K. outside London. The M8, a major east-west motorway connecting Glasgow with Edinburgh and linking to the UK motorway network, passes within 1 km of the central business district. This motorway, whilst providing excellent communication links to the outside world, brings specific problems, particularly in peak periods, when commuting traffic mixes with long distance traffic resulting in conflict and delay both upon the M8 and upon the surrounding road network.

A Changing Transport Policy

It was recognised in the mid to late 1980's that large scale road building was not the answer to Glasgow's traffic problems. Hence, a balanced programme of physical capacity enhancements and the use of ITS techniques was adopted, to make optimal use of the existing road infrastructure and encouraging, where possible, a modal shift towards public transport. The Council's transport policies support wider objectives to improve the quality of life for residents and aid the continued regeneration of the local economy. In following these objectives Glasgow continues to be at the forefront of emerging technologies.

Glasgow City Council are strongly committed to improving road safety and aims to achieve or better the UK Government's national target of a third reduction in casualties by the year 2000. In the past five years Glasgow has seen a 52% reduction in fatal casualties and a 19% reduction in other injuries. The authority are convinced that telematics applications such as ramp metering can make a valuable contribution to this aim.

Glasgow and the Clydeside conurbation has a strong history of involvement in co-operative projects within the European Union, such as EUROCOR (European Urban Corridor Control). Similarly it has a history of innovation within the traffic control field, being the first European city to be equipped with an urban traffic control system, some 30 years ago. It is recognised that a continuing forum for both development and an exchange of ideas is needed if innovation is to be maintained. To this end Glasgow continues to be actively involved in European research, development and project implementation.

Glasgow Within The TA*BASCO* Project

The TA*BASCO* project, involves demonstrations of telematics applications throughout Europe. Glasgow City Council, the project's co-ordinating partner, is actively participating in specific work areas involving Variable Message Sign (VMS) assisted park and ride, BALANCE traffic control to assist public transport through urban signalised junctions, and an urban integrated control strategy that harmonises the interaction between the motorway and urban road networks. This paper concerns the traffic safety implications of the implementation of ramp metering as part of integrated control.

Ramp metering uses the ALINEA control strategy developed by the Technical University of Munich and tested within the DRIVE I CHRISTIANE project, and is located at the M8 junction 16 eastbound on-ramp, figure one. Ramp metering was envisaged, initially, as a solution to a recurring PM peak period problem, but could conceivably be triggered at any time of the day. VMS signs are located on each urban approach to the ramp. When ramp metering is operational VMS on each urban approach advertise the availability of alternative routes to the north and south of the M8 that take traffic to the downstream junction 15. During times of severe congestion or incident the diversion route can be prescribed with the on-ramp signed as closed. Vehicle passage along the urban alternative routes is eased by the selection of appropriate signal plans.

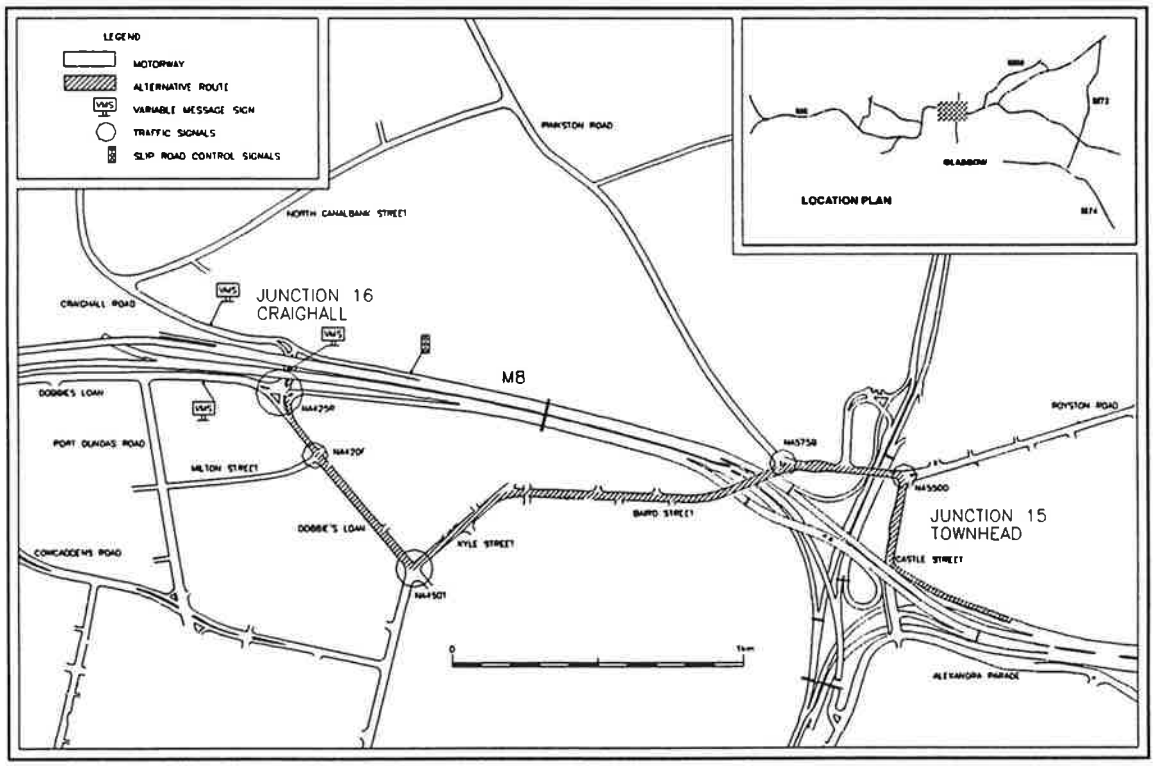

Figure 1: Glasgow Integrated Control Study Area

Evaluating Integrated Traffic Control

It was considered that integrated control should aim to increase network efficiency whilst recognising the potential impacts upon the urban road network and, in particular, the safety and environmental impact upon the road network as a whole.

Evaluation follows the guidelines given by the European Union DGXIII project CONVERGE. These guidelines aim to ensure cross site comparability. Close co-operation with implementation in Lyon and Munich following a common set of objectives aids the demonstration of generic transferability of the control processes developed.

Network Impact

Road impact statistics are produced by analysing detector data collected continuously for both the motorway and urban networks throughout the evaluation period, approximately one year. This involves the storage of approximately 2Gb of data which is first cleaned, then checked and manipulated using an off line database model. Output is in the form of link based statistics relating to vehicular delay, emissions and noise as well as an analysis of vehicle flow characteristics. Motorway detector sites provide flow, speed and occupancy measurements collected at 3 minute intervals. This allows a detailed level of understanding of traffic flow behaviour on a microscopic level to be developed. Flow data on the urban routes is collected at 15 minute intervals. Whilst coarser, it is still detailed enough to provide an accurate assessment of delay characteristics.

Evaluation of ramp metering has shown a significant increase in throughput on the M8. Figure 2 compares before and after ramp metering speed flow curves on the M8 immediately up stream of the controlled ramp. Figure 2 clearly shows an increase in overall capacity and a smoother, more clearly defined, speed flow curve as a result of the implementation of ramp metering. As a result of managed entry to the motorway the incidence and severity of developed shock waves have been shown to decrease.

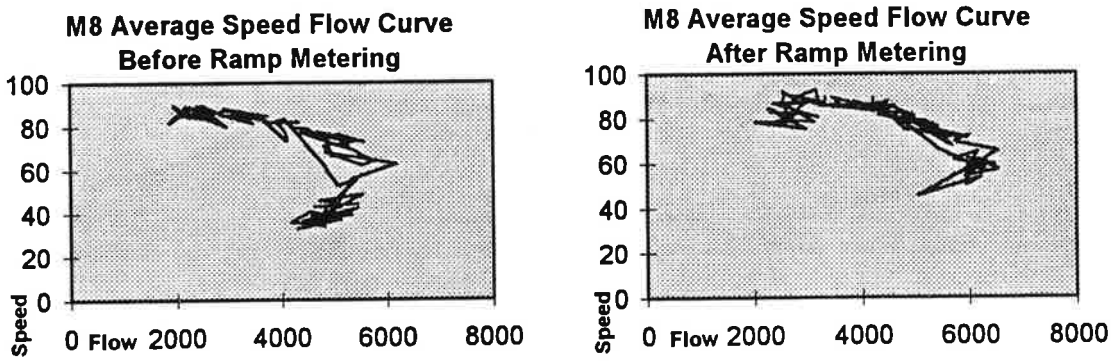

Figure 2: M8 Speed Flow Curves, Before and After Ramp Metering

Considering the network as a whole it has been shown that ramp metering had reduced flow upon the on ramp and had increased flow upon the urban alternative route. As a result of increased traffic levels upon the urban diversion routes, there was a subsequent increase in delay and therefore journey time. Overall however it was found that more traffic was travelling through the network, suffering less delay. A reduction in delay has compensated for the increase in traffic levels ensuring that emission and noise levels remain constant.

Safety Evaluation And A Safety Hypothesis

Road safety is a primary concern of both the Scottish Office and Glasgow City Council and a key motivator in the implementation of motorway lane control as part of NADICS. Within the evaluation period it was considered neither accurate, in terms of statistical integrity, or beneficial, in terms of a true understanding of safety, to consider incident occurrence only as an indicator of safety. In preference conflict analysis was undertaken. This analysis used the UK Defence Research Agency's ASSET-2 image processing software to analyse video footage recorded by CCTV. Video images were used for weekday two hour PM peak periods two weeks before and two weeks after the implementation of ramp metering.

The conflict analysis considered the change in merge behaviour as a result of ramp metering. It was hypothesised that the implementation of ramp metering would enhance the merge of traffic joining the motorway thus reducing avoidance manoeuvres upon the motorway and reducing the incidence of potential collision trajectories upon the motorway. Anecdotal evidence had shown vehicles were merging at a lower speed and using the full length of the ramp in order to select an appropriate merge point. This was considered to be a product of the forced stop and subsequent requirement to accelerate before merging. The improved speed flow on the motorway approach to the slip, demonstrated in figure two, together with a smoother merge was thought to reduce the incidence of breaking and subsequent avoidance manoeuvring. It was considered that these factors would be effective indicators of safety that could be quantified. The indicators of safety were therefore considered to be headway compression and lane switching on the motorway at the merge approach, time to collision between merging and motorway vehicles and point of merge.

The ASSET-2 System

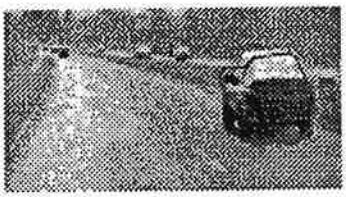

Figure 3: Image Tracking

ASSET-2 is A Scene Segmenter Establishing Tracking - Version 2 developed by the UK Defence Research Agency. ASSET-2 is a complete real-time vision system for segmentation and tracking of independently moving objects. It is a system designed to require no camera calibration or motion registration performing all calculations in the image plane. Information gained from the motion of two dimensional features is integrated with one dimensional boundaries. ASSET-2 achieves automatic instantiation of tracking for each new object detected, and any number of objects can be tracked. Through the accurate tracking of single objects occlusion of one object by another should not be a problem. The temporal integration of segmentation information in such a robust and flexible way is a step forward in the area of image sequence understanding. ASSET-2 starts by tracking 2D image features as they move across the picture over time, to get a sparse image flow field. The flow field is then segmented into clusters which have internally consistent flow variation (using a first-order - six parameter - fit to the flow field) and which have different flow to each other and to the background. The cluster shapes, figure three, are filtered over time to give improved accuracy and robustness. ASSET-2 has been implemented as a real-time system on PowerPC/Transputer image processing equipment.

The Use Of ASSET-2 In Glasgow

In dense traffic conditions, which persisted for much of the filming period, there is little visible roadway between following vehicles, which are moving at similar speeds. This prevents the resolution and tracking of individual vehicles, since the inter-vehicle and intra-vehicle separation of corner points is similar, and frequently results in the segmentation of a large part of the traffic queue as a single object. The problem is aggravated by the fact that very few corner points are detected on the road surface in images from the high mast CCTV cameras, due to the effects of slight defocusing and camera motion, which results in the merging of flow regions corresponding to vehicles in adjacent lanes.

Therefore in order to analyse the data it was necessary to determine and track the motion of corner features, rather than attempting to track individual objects. This required an analysis of the number and velocity of corner point tracks crossing designated trip-wires within the scene, and deriving vehicle counts by assuming an average number of corners per vehicle.

Analysis in such a way prevented the measurement of time to collision values and required the interpretation of headway compression from measurements of deceleration on the approach to the on-ramp.

Lane switching movements were detected using trip wires placed parallel to the lane markings. Vehicle flows were determined using trip wires placed across each lane and lane accelerations estimated from the difference between average speed measurements taken from a pair of trip wires in the same lane.

False triggering by spuriously tracked corner points (which arise from effects of image noise as opposed to a moving object) is reduced by constraining the permissible speed and angle of attack of corners crossing the trip wire. In addition the trip wires are offset from the lane boundaries to reduce the incidence of triggering by vehicles in adjacent lanes which typically occurs when high vehicles obscure part of the adjacent lane.

Merge Analysis Before Ramp Metering

Figure 4 shows the mean speed change on the M8 approach to the on ramp in the 'before ramp metering' period for the two hour PM peak. A positive figure indicates a positive speed difference between a measurement point 30 metres and 90 metres up stream of the on ramp.

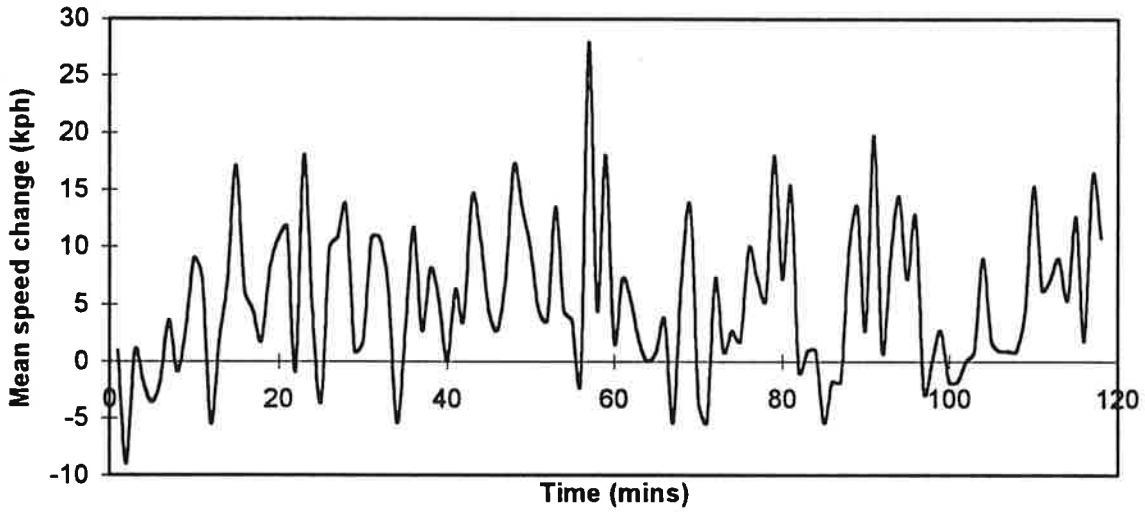

Figure 4: Mean Speed Change on Approach to On-Slip

Figure 4 clearly shows a decrease in vehicle speed on the immediate approach to the on slip caused by the disruption effects of merging traffic. Observation during this period shows substantial shock wave development that reaches to, and beyond, the adjacent up stream on ramp.

Figure 5 compares the incidence of lane switching on the approach to the on ramp at points 30 metres and 150 metres up stream of the on-ramp. From figure 5 it can be seen that the incidence of lane switching increases on the approach to the on-ramp with up to 6 vehicles per minute switching between lanes one and two within 30 metres of the on slip. This would indicate late decision making and avoidance manoeuvres that would add to flow disruption and shock wave creation.

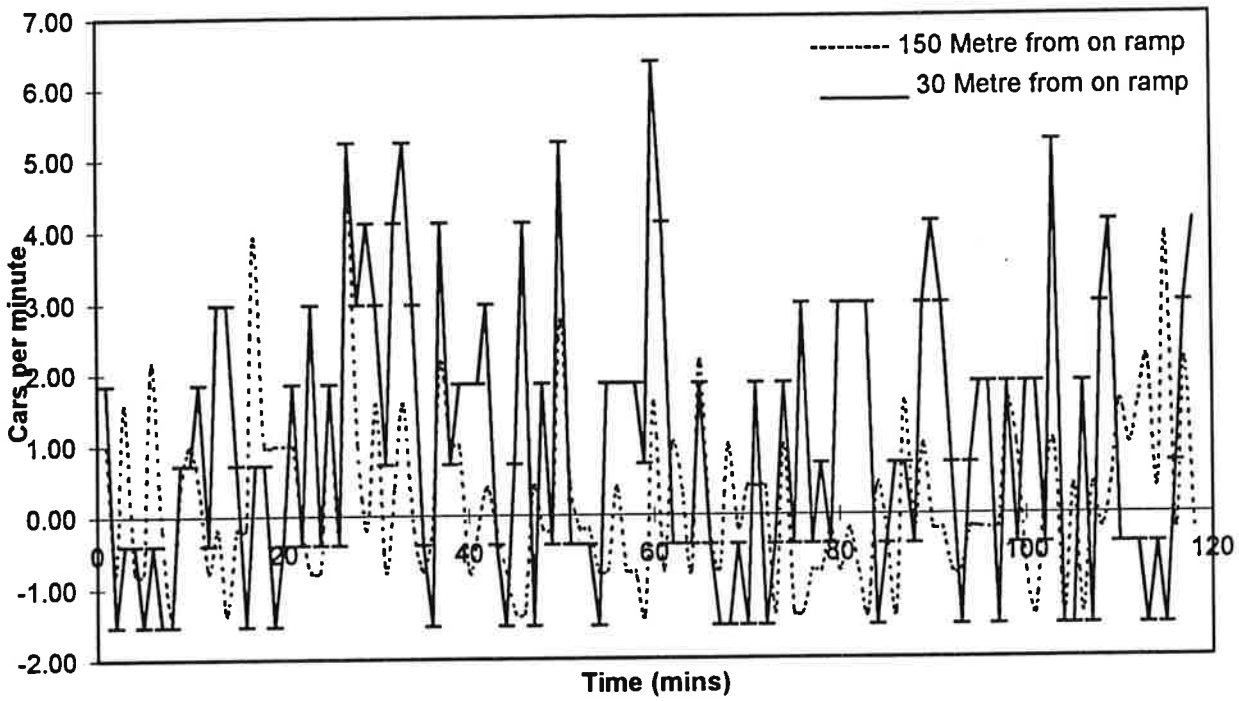

Figure 5: Lane Switching Between On M8 Approach to On Ramp

Figure 6 shows the merge point of vehicles joining the M8. An early merge is defined as a merge that takes place within the first half of the on ramp, consequently a late merge takes place within the latter half of the on ramp. An infringement indicates a merge taking place within the hatching separating the on-ramp from the motorway. Figure 6 shows a reluctance to use the full merge length with significant proportions of vehicles choosing to merge within the hatched area separating the motorway and the on-ramp. This phenomena may be encouraged by low vehicle speed upon the motorway but also may contribute to flow disruption upon the motorway.

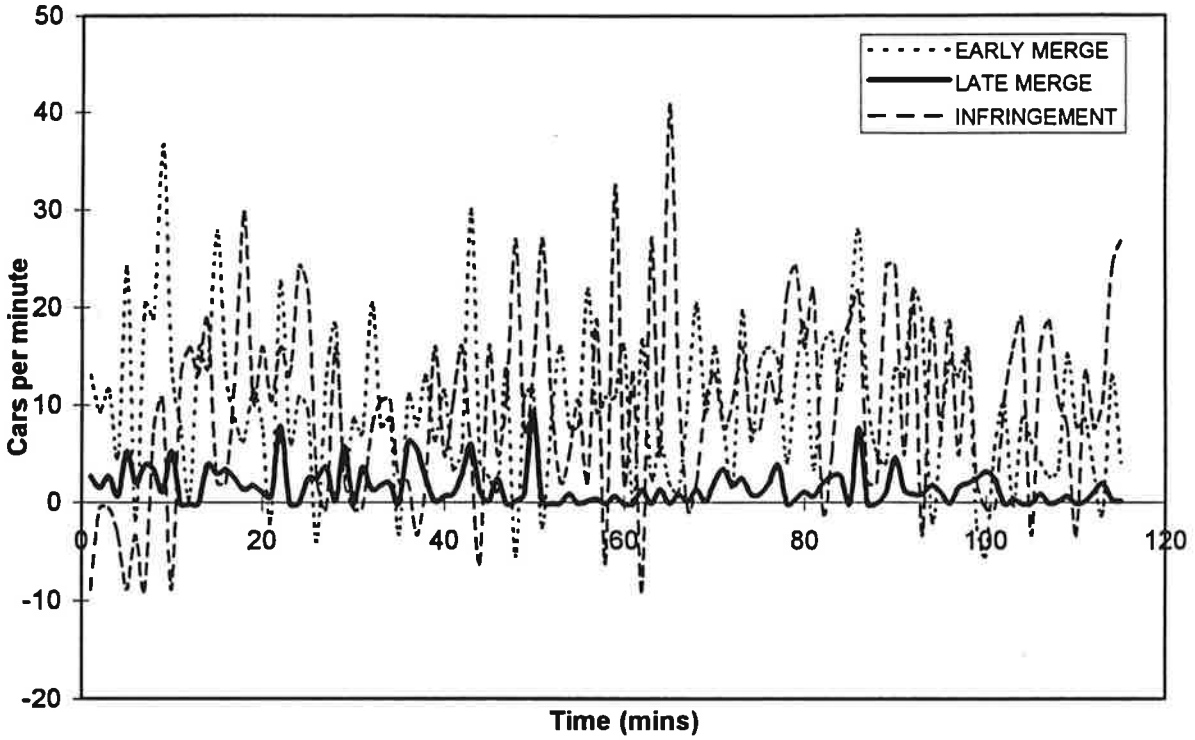

Figure 6: Merge Point of Vehicles Joining M8

Conclusion

This paper has shown how the ASSET-2 image processing system has been used to assess traffic safety on the M8 motorway in Glasgow prior to the implementation of ramp metering. A traffic safety hypothesis has been developed from an examination of the network performance of ramp metering and the ability of image processing to test this hypothesis has been examined. It is considered that ramp metering , by virtue of regulating motorway entry and smoothing the speed flow relationship upon the motorway, ensures optimum use of the motorway merge, reduces the incidence of breaking and avoidance manoeuvres upon the motorway.

The ability of image processing to measure these effects has been frustrated by problems of differentiating between images caused by dense slow moving traffic exacerbated by camera shake and focusing. The latter could be overcome by using dedicated camera positions placed directly above the area of study.

These problems have necessitated the adoption of alternative traffic safety indicators as a proxy for those first derived. An examination of the motorway merge prior to ramp metering has shown that there is a significant decrease in vehicle speed on the approach to the on ramp causing the development of shock waves, that the incidence of lane switching increases significantly on the approach to the on-ramp and that merging vehicles choose to merge early in preference to using the full merge length.

Further work, to be presented at the ICTC conference in November 1997, will compare data traffic safety analysis undertaken before and after the implementation of ramp metering. It is considered that the work described has provided an opportunity to both assess the potential of image processing to provide a measure of traffic safety and the potential safety benefits of ramp metering. This will be have benefits for ramp metering and for other related work, such as microscopic driver reaction to VMS, both within the TA*BASCO* project and elsewhere.